AMENDMENTS TO THE SPECIFICATION

Amend the specification by inserting before the first line the sentence:

This is a divisional of Application No. 09/574,015 filed May 19, 2000; the disclosure of which is incorporated herein by reference.

Please amend page 3, first full paragraph as follows:

Therefore, it is an object of the present invention to provide a liquid consumption status detecting method and liquid container capable of accurately detecting a liquid consumption status and dispensing with a complicated sealing structure. It is another object of the present invention to provide a liquid consumption status detection method, which [does] is not [to be] influenced by the unstable measuring signal generated at the early stage of the measuring of the liquid consumption status. It is a further [other] object of the present invention to provide the liquid consumption status detection method which can reduce the time for detecting the liquid consumption status. It is still a further [other] object of the present invention to provide a control circuit for a measuring apparatus to [realizes] realize the above mentioned detection method. These objects are achieved by combinations described in the independent claims. The dependent claims define further advantageous and exemplary combinations of the present invention.

Please amend page 4, second full paragraph as follows:

The detection method can be provided such that the measurement step is operated after a predetermined time period has elapsed from the activation step. The detection method can be provided such that the measurement step is operated after the vibrations of the detection device several times. The detection method can be provided such that the measurement step comprises a step of measuring a time period in between a predetermined plurality of peaks of the residual vibration. The detection method [according] can be provided such that the measurement step comprises a step of measuring a number of peaks of the residual vibration within a predetermined time period.

Please amend page 4, paragraph bridging pages 4 and 5 as follows:

The detection method can be provided such that the measurement step comprises a step of measuring a counter electromotive voltage generated by the detection device in accordance

with the residual vibration thereof. The detection method may further [comprises] comprise steps of: measuring previously a first frequency value of the residual vibration of the detection device when the liquid container is full of liquid, the frequency is regarded as a reference frequency value; measuring a second frequency value of the residual vibration of the detection device when liquid in the liquid container is consumed; comparing the reference frequency with the second frequency; and judging the consumption status of the liquid contained in the liquid container in accordance with a result of the comparing step.

Please amend page 7, first full paragraph as follows:

The detection control circuit can be provided such that a drive voltage generated between the source of the P-channel FET and the N-channel FET is applied to the detection device. The detection control circuit can be provided such that the detection circuit segment comprises a counter for counting the number of the [vibration] vibrations of the residual vibration within a predetermined time period, and the detection circuit segment judges the liquid consumption status in accordance with the counted value. The detection control circuit can be provided such that the detection circuit segment comprises a counter for counting a number of clocks within a time period where the residual vibration vibrates a predetermined number of times, the clock has a cycle shorter than the vibration cycle of the residual vibration.

Please amend page 9, first full paragraph as follows:

This summary of the invention does not necessarily describe all the necessary features of the present invention. The present invention may also be a sub-combination of the above described features. The above and other features and advantages of the present invention will become more apparent from the following description of embodiments taken in conjunction with the accompanying drawings.

Please amend page 9, ninth full paragraph as follows:

Fig. 8 shows a further [other] embodiment of the recording apparatus control unit 2000 shown in Fig. 6.

Please amend page 11, fourth full paragraph as follows:

Figs. 31A and 31B show [another] other embodiments of the ink cartridge 180 shown in Fig. 30.

Please amend page 11, paragraph bridging pages 11 and 12 as follows:

The basic concept of the present invention is to detect a state of the liquid inside a liquid container by utilizing vibration phenomena. The state of the liquid includes whether or not the liquid in the liquid container is empty, amount of the liquid, level of the liquid, types of the liquid and combination of liquids. Several specific methods [realizing] for detection of the state of the liquid inside the liquid container utilizing vibration phenomena are considered. For example, a method is considered in which the medium and the change of its state inside the liquid container are detected in such a manner that an elastic wave generating means generates an elastic wave inside the liquid container, and then the reflected wave which is thus reflected by the liquid surface or a wall disposed counter thereto is captured. There is another method in which a change of acoustic impedance is detected by vibrating characteristics of a vibrating object. As a method utilizing the change of the acoustic impedance, a vibrating portion of a piezoelectric device or an actuator having a piezoelectric element therein is vibrated. Thereafter, a resonant frequency or an amplitude of the back electromotive force waveform is detected by measuring the back electromotive force which is caused by residual vibration which remains in the vibrating portion, so as to detect the change of the acoustic impedance. As another method utilizing the change of the acoustic impedance, the impedance characteristic or admittance characteristic of the liquid is measured by a measuring apparatus such as an impedance analyzer and a transmission circuit, so that the change of a current value or a voltage value, or the change of the current value or voltage value due to the frequency caused by the vibration given to the liquid is measured. The operational principles of the elastic wave generating means and the piezoelectric device or actuator will be described at a later stage.

Please amend page 15, paragraph bridging pages 14 and 15 as follows:

Therefore, the main portion of the piezoelectric layer 160 has a structure to be sandwiched by the main portion of the upper electrode 164 and the main portion of the lower electrode each from right side face and back side face, and thus the main portion of the

piezoelectric layer 160 can effectively drive and deform the piezoelectric layer 160. The circular portion, which is a main portion of each of the piezoelectric layer 160, the upper electrode 164, and the lower electrode 166, forms the piezoelectric element in the actuator 106. As explained above, the electric element contacts with the vibrating plate. Within the circular portion of the upper electrode 164, circular portion of the piezoelectric layer 160, the circular portion of the lower electrode, and the opening 161, the opening 161 has the largest area. By this structure, the vibrating region which actually vibrates within the vibrating plate is determined by the opening 161. Furthermore, each of the circular portion of the upper electrode 164 and the circular portion of the piezoelectric layer 160 and the circular portion of the lower electrode has smaller area than the area of the opening 161[,]. The vibrating plate becomes easily [vibrate] vibrateable. Within the circular portion of the lower electrode 166 and the circular portion of the upper electrode 164 which connects to the piezoelectric layer 160 electrically, the circular portion of the lower electrode 166 is smaller than the circular portion of the upper electrode 164. Therefore, the circular portion of the lower electrode 166 determines the portion which generates the piezoelectric effect within the piezoelectric layer 160.

Please amend page 16, second full paragraph as follows:

Furthermore, because the vibrating section of the vibrating plate 176 has a circular shape, the lower resonant mode, for example, the primary resonant mode dominates on the resonant mode of the residual vibration of the piezoelectric layer 160, and thus the single peak appears on the resonant mode. Therefore, the peak and the noise can be distinguished clearly so that the resonant frequency can be clearly detected. Furthermore, the accuracy of the detection of the resonant frequency can be further increased by [enlarge] enlarging the area of the vibrating section of the circular [shape] shaped vibrating plate 176, because the difference of the amplitude of the counter electromotive force, and the difference of the amplitude of the resonant frequency [occurred by] that occurs depending on whether the liquid exists inside the liquid container, increase.

Please amend page 17, paragraph bridging pages 16 and 17 as follows:

The displacement generated by the vibration of the vibrating plate 176 is larger than the displacement generated by the vibration of the base plate 178. The actuator 106 has a two [layers] layer structure that is constituted by the base plate 178 having a small compliance which means it is difficult to be displaced by the vibration, and the vibrating plate 176 having a large compliance which means it is easy to be displaced by the vibration. By this two [layers] layer structure, the actuator 106 can be reliably fixed to the liquid container by the base plate 178 and at the same time the displacement of the vibrating plate 176 by the vibration can be increased. Therefore, the difference of the amplitude of the counter electromotive force and the difference of the amplitude of the resonant frequency [depended] depends on whether the liquid exists inside the liquid container increases, and thus the accuracy of the detection of the resonant frequency increases. Furthermore, because the compliance of the vibrating plate 176 is large, the attenuation of the vibration decreases so that the accuracy of the detection of the resonant frequency increases. The node of the vibration of the actuator 106 locates on the periphery of the cavity 162, that is, around the margin of the opening 161.

Please amend page 18, paragraph bridging pages 18 and 19 as follows:

It is preferable to use lead zirconate titanate (PZT), lead lanthanum zirconate titanate (PLZT), or piezoelectric membrane without using lead as a material for the piezoelectric layer 160. It is preferable to use zirconia or alumina as a material of the base plate 178. Furthermore, it is preferable to use the same material as base plate 178 for a material of vibrating plate 176. The metal such as gold, silver, copper, platina, aluminum, and nickel having [a] an electrical conductivity can be used for the material of the upper electrode 164, the lower electrode 166, the upper electrode terminal 168, and the lower electrode terminal 170.

Please amend page 19, second paragraph as follows:

The actuator 106 shown in the Fig. 1 and Fig. 2 is mounted on the predetermined position on the liquid container so that the cavity 162 can contact [w3ith] with the liquid contained inside the liquid container. When the liquid container is filled with liquid sufficiently, the inside and outside of the cavity 162 is filled with liquid. On the other hand, if the liquid inside the liquid container is consumed and the liquid level is decreased under the mounting position of the

actuator, there are conditions that liquid does not [exit] exist inside the cavity 162 or that liquid is remained only in the cavity 162 and air [exits on] exists outside the cavity 162. The actuator 106 detects at least the difference in the acoustic impedance occurred by this change in condition. By this detection of the difference in acoustic impedance, the actuator 106 can [detects the] detect whether the liquid is sufficiently filled in the liquid container or liquid is consumed more than the predetermined level. Furthermore, the actuator 106 can [detects] detect the type of the liquid inside the liquid container.

Please amend page 19, paragraph bridging pages 19 and 20 as follows:

To detect the acoustic impedance of a medium, an impedance characteristic or an admittance characteristic is measured. To measure the impedance characteristic or the admittance characteristic, for example, a transmission circuit can be used. The transmission circuit applies a constant voltage on the medium and [measure] measures a current flow through the medium with changing a frequency. The transmission circuit provides a constant current to the medium and measures a voltage applied on the medium with changing a frequency. The change in current value and the voltage value measured at the transmission circuit shows the change in acoustic impedance. Furthermore, the change in a frequency fm, which is a frequency when the current value or the voltage value becomes maximum or minimum, also shows the change in acoustic impedance.

Please amend page 22, second full paragraph as follows:

[Depends] Depending on the mounting position and mounting angle of the actuator 106 on the liquid container, there is a case in which the liquid attaches to the vibrating region of the actuator even if the liquid level in the liquid container is lower than the mounting position of the actuator. When the actuator detects the existence of the liquid only from the existence of the liquid on the vibrating region, the liquid attached to the vibrating region of the actuator prevents the accurate detection of the existence of the liquid. For example, [If] if the liquid level is lower than the mounting position of the actuator, and the drop of the liquid attaches to the vibrating region by the waving of the liquid caused by the shaking of the liquid container caused by the movement of the carriage, the actuator 106 will [misjudges] misjudge that there is enough liquid

in the liquid container. In this way, the malfunction can be prevented by using the actuator having a cavity.

Please amend page 24, first full paragraph as follows:

Generally, the resonant frequency fs can be expressed as the following[.]:

$$fs = 1/ (2 * \pi * (M*Cact)^{1/2} \qquad (1)$$

where M denotes the sum of an inertance of the vibrating section Mact and an additional inertance M'; Cact denotes a compliance of the vibrating section.

Please amend page 26, second full paragraph as follows:

Fig. 2(C) shows the cross section of the actuator 106 when the liquid is sufficiently filled in the liquid container, and the periphery of the vibrating region of the actuator 106 is filled with the liquid. The M'max shown in Fig. 2(C) shows the maximum value of the additional inertance when the liquid is sufficiently filled in the liquid container, and the periphery of the vibrating region of the actuator 106 is filled with the liquid. The M'max can be expressed as

$$M'max = (\pi * \rho / (2*k^3)) * (2* (2*k*a)^3 / (3*\pi)) / (\pi*a^2)^2 \qquad (4)$$

where "a" [a] denotes the radius of the vibrating section; ρ denotes the density of the medium; and k denotes the wave number. The equation (4) applies when the vibrating region of the actuator 106 is a circular shape having the radius of "a". The additional inertance M' shows the quantity that the mass of the vibrating section is increased virtually by the effect of the medium which exists around the vibrating section.

Please amend page 26, fifth full paragraph as follows:

The wave number k can be expressed by following equation.

$$k = 2 * \pi * fact/c \qquad (5)$$

where fact denotes the resonant frequency of the vibrating section when the liquid does not contact with the vibrating section; and "c" [c] denotes the speed of the sound propagate through the medium.

Please amend page 27, first full paragraph as follows:

Fig. 2(E) shows the cross section of the actuator 106 when the liquid in the liquid container is consumed, and there is no liquid around the vibrating region of the actuator 106, and the liquid remains in the cavity 162 of the actuator 106. The equation (4) shows the maximum inertance M'max determined by such as the ink density ρ when the liquid container is filled with the liquid. On the other hand, if the liquid in the liquid container is consumed and liquid existed around the vibrating section of the actuator 106 becomes gas or vacuum with the liquid remaining in the cavity 162, the M' can be expressed as following equation.

$$M' = \rho * t/S \qquad (6)$$

where t denotes the thickness of the medium related to the vibration; <u>"S"</u> [S] denotes the area of the vibrating region of the actuator 106. If this vibrating region is <u>a</u> circular shape having a radius of "a", the <u>"S"</u> [S] can be shown as $S = \pi * a^2$. Therefore, the additional inertance M' follows the equation (4) when the liquid is sufficiently filled in the liquid container, and the periphery of the vibrating region of the actuator 106 is filled with the liquid. The additional inertance M' follows the equation (6) when the liquid in the liquid container is consumed, [and] there is no liquid [exits] around the vibrating region of the actuator 106, and the liquid [is remained] <u>remains</u> in the cavity 162.

Please amend page 27, second full paragraph as follows:

Here, as shown in Fig. 2 (E), let the additional inertance M', when the liquid in the liquid container is consumed, [and] there is no liquid [exits] around the vibrating region of the actuator 106, and the liquid [is remained] <u>remains</u> in the cavity 162, [as] <u>be</u> M' cav to distinguish with the additional inertance M' max, which is the additional inertance when the periphery of the vibrating region of the actuator 106 is filled with the liquid.

Please amend page 28, first full paragraph as follows:

Here, the parameters related to the status of the medium are density of the medium ρ and the thickness of the medium t in equation (6). When the liquid is sufficiently filled in the liquid container, the liquid contacts with the vibrating section of the actuator 106. When the liquid is

insufficiently filled in the liquid container, the liquid is remained in the cavity, or the gas or vacuum contacts with the vibrating section of the actuator 106. If [let] the additional inertance—during the process of the shifting from the M'max of Fig. 2(C) to the M'var of Fig. 2(E) when the liquid around the actuator 106—is consumed, because the thickness of the medium "t" [t] changes according to the containing status of the liquid in the liquid container, the additional inertance M'var changes, and resonant frequency also changes. Therefore, the existence of the liquid in the liquid container can be detected by [specify] specifying the resonant frequency. Here, if [let] t = d, as shown in Fig. 2(E) and using the equation (6) to express the [m'cav] M'cav, the equation (7) can be obtained by substituting the thickness of the cavity "d" into the "t" in the equation (6).

$$M'cav = \rho * d/S \qquad (7)$$

Please amend page 29, first full paragraph as follows:

When ink is sufficiently filled in the ink container, and ink is filled around the vibrating region of the actuator 106, the maximum additional inertance M'max becomes the value shown in the equation (4). When the ink is consumed, and there is no ink around the vibrating region of the actuator 106, and the ink remains in the cavity 162, the additional inertance M'var is calculated by the equation (6) based on the thickness of the medium "t" [t]. Because the "t" used in the equation (6) is the thickness of the medium related to the vibration, the process during which the ink is consumed gradually can be detected by forming the "d" (refer to Fig. 1(B)) of the cavity 162 of the actuator 106 as small as possible, that is, forming the thickness of the base plate 178 as sufficiently thinner as possible (refer to Fig. 2(C)). Here, let [the] t-ink [as] be the thickness of the ink involved with the vibration and t-ink-max [as] be the value of t-ink when the additional inertance is M'max. For example, the actuator 106 is mounted on the bottom of the ink cartridge horizontally to the surface of the ink. If ink is consumed, and the ink level becomes lower than the height t-ink-max from the actuator 106, the M'var gradually changes according to the equation (6), and the resonant frequency fs gradually changes according to the equation (1). Therefore, until the ink level is within the range of "t", the actuator 106 can gradually detect the ink consumption status.

Please amend page 30, second full paragraph as follows:

In detail, the case when the actuator 106 can detect the process of the gradual consumption of the ink is the case when the liquid and gas having different density with each other are existed together and also involved with vibration. According to the gradual consumption of the ink, the liquid decreases with increasing of the gas in the medium involved with the vibration around the vibrating region of the actuator 106. For example, the case when the actuator 106 is mounted on the ink cartridge horizontally to the ink surface, and t-ink is smaller than the t-ink-max, the medium involved with the vibration of the actuator 106 includes both of the ink and the gas. Therefore, the following equation (8) can be obtained if [let] the area of the vibrating region of the actuator 106 [as] is "S" [S] and the [express the] status when the additional inertance is below M'max in the equation (4) is expressed by additional mass of the ink and the gas.

Please amend page 31, first full paragraph as follows:

When the actuator 106 is provided on the ink cartridge substantially perpendicular to the ink surface, the status can be expressed as the equivalent circuit, not shown in the figure, on which the region, where the medium involved with the vibration of the actuator 106 is ink only, and the region, where the medium involved with the vibration of the actuator 106 is gas, can be expressed as parallel circuit. If [let] the area of the region where the medium involved with the vibration of the actuator 106 is ink only, expressed as Sink, and [let] if the area of the region where the medium involved with the vibration of the actuator 106 is gas only, expressed as Sair, the following equation (9) can be obtained.

Please amend page 32, first full paragraph as follows:

In the case when the thickness of the base plate 178 is thick, that is, the depth of the cavity 162 is deep and "d" [d] is comparatively close to the thickness of the medium t-ink-max, or in the case when using an actuator having a very small vibrating region compared to height of the liquid container, the actuator does not detect the process of the gradual decrease of the ink but actually detects whether the ink level is higher or lower than the mounting position of the actuator. In other words, the actuator detects the existence of the ink at the vibrating region of

the actuator. For example, the curve Y in Fig. 3(A) shows the relationship between the ink quantity in the ink tank and the resonant frequency fs of the vibrating section when the vibrating section is small circular shape. The curve Y shows that the resonant frequency fs of the ink and the vibrating section changes extremely during the range of change of ink quantity Q, which corresponds to the status before and after the ink level in the ink tank passes the mounting position of the actuator. By this [changes] change of the resonant frequency fs, it can be detected whether the ink quantity remained in the ink tank is more than the predetermined quantity.

Please amend page 32, paragraph bridging pages 32 and 33 as follows:

The method of using the actuator 106 for detecting the existence of the liquid is more accurate than the method which calculates the quantity of ink consumption by the software because the actuator 106 detects the existence of the ink by directly contacting with the liquid. Furthermore, the method using an electrode to [detects] detect the existence of the ink by conductivity is influenced by the mounting position to the liquid container and the ink type, but the method using the actuator 106 to [detects] detect the existence of the liquid [does] is not influenced by the mounting position to the liquid container, or by [and] the ink type. Moreover, because both of the oscillation and detection of the existence of the liquid can be done by the single actuator 106, the number of the sensor mounted on the liquid container can be reduced [compare] compared to the method using separate sensor for oscillation and the detection of the existence of the liquid. Therefore, the liquid container can be manufactured at a low price. Furthermore, the sound generated by the actuator 106 during the operation of the actuator 106 can be reduced by setting the vibrating frequency of the piezoelectric layer 160 out of the audio frequency.

Please amend page 33, first full paragraph as follows:

Fig. 3(B) shows the relationship between the density of the ink and the resonant frequency fs of the ink and the vibrating section of the curve Y shown in Fig. 3(A). Ink is used as an example of liquid. As shown in Fig. 3(B), when ink density increases, the resonant frequency fs decreases because the additional inertance increases. In other words, the resonant frequency fs [are] is different [with] depending on the [types] type of the ink. Therefore, [By] by

measuring the resonant frequency fs, it can be confirmed whether the ink of a different density has been mixed together during the re-filling of the ink to the ink tank.

Please amend page 33, third full paragraph as follows:

The condition when the actuator 106 can accurately [detects] detect the status of the liquid will be explained in detail in following. The case is assumed that the size and the shape of the cavity is designed so that the liquid can be remained in the cavity 162 of the actuator 106 even when the liquid inside the liquid container is empty. The actuator 106 can detect the status of the liquid even when the liquid is not filled in the cavity 162 if the actuator 106 can detect the status of the liquid when the liquid is filled in the cavity 162.

Please amend page 34, paragraph bridging pages 34 and 35 as follows:

Here, the M'cav is the mass of the liquid of the volume which is substantially equal to the volume of the cavity 162. Therefore, the condition, which can detect the status of the liquid accurately, can be expressed as the condition of the volume of the cavity 162 from the inequality M'max > M'cav. For example, if [let] the radius of the opening 161 of the circular shaped cavity 162 [as] is "a" and the thickness of the cavity 162 [as] is "d", then the following inequality can be obtained[.]:

$$M'max > \rho * d/\pi a^2 \qquad (10)$$

By expanding the inequality (10), the following condition can be obtained.

$$a/d > 3*\pi/8 \qquad (11)$$

The [inequality] inequalities (10) and (11) are valid only when the shape of the cavity 162 is circular. By using the equation when the M'max is not circular and substituting the area πa^2 with its area, the relationship between the dimension of the cavity such as a width and a length of the cavity and the depth can be derived.

Please amend page 36, paragraph bridging pages 36 and 37 as follows:

Even if each of the ink cartridges of the same type contain the same kinds of, for example, same color of ink with same quantity, the value of the generated resonant frequency are subtly different for each ink cartridges owing to a difference in each individual actuators 106.

Therefore, the frequency is measured when an ink cartridge is in ink-full status, and the data of the frequency is previously stored in the semiconductor memory device 7 or the memory inside the recording apparatus. Then, by comparing the frequency measured during the consumption of the ink in each ink [cartridges] cartridge with the frequency stored in the memory as a reference value, the ink consumption status can be detected for each ink [cartridges] cartridge. For example, the frequency when the ink cartridge is in ink-full status is measured when the new ink cartridge is mounted on the recording apparatus, and the value of the frequency is stored in the memory as a reference value. Then, the ink consumption status can be detected by comparing the frequency measured when the ink in the ink cartridge is consumed with the frequency when the ink cartridge is in ink-full status as a reference value. Moreover, the frequency when the ink cartridge is in ink-full status is previously measured during the manufacturing process of the ink cartridge, and the value of the measured frequency is stored in the semiconductor memory device 7 as a reference value. Then, the ink consumption status can be detected by comparing the frequency measured when the ink in the ink cartridge is consumed with the frequency when the ink cartridge is in ink-full status as a reference value.

Please amend page 38, first full paragraph as follows:

The patterns of numerical value for each [combinations] combination of the primary mode resonant frequency and the secondary mode resonant frequency are different by the difference of each residual quantity of ink in each of ink cartridges A, B, and C. Therefore, the residual quantity of ink contained in the ink cartridge, which is mounted on the recording apparatus, can be judged by measuring both the primary mode resonant frequency and the secondary mode resonant frequency.

Please amend page 41, first full paragraph as follows:

Furthermore, as other embodiments, the wave number of the voltage waveform of the counter electromotive force during the predetermined period can be counted. More specifically, after the actuator 106 oscillates, the digital signal is set to be high during the predetermined period, and the number of the times when the analog signal [is get across] crosses the

predetermined reference voltage from the low voltage side to the high voltage side is counted. By measuring the count number, the existence of the ink can be detected.

Please amend page 41, second full paragraph as follows:

Furthermore, it can be known by comparing Fig. 5(A) with Fig. 5(B), the amplitude of the waveform of the counter electromotive force is different when the ink is filled in the ink cartridge and when the ink is not [existed] in the cartridge. Therefore, the ink consumption status in the ink cartridge can be detected by measuring the amplitude of the waveform of the counter electromotive force without calculating the resonant frequency. More specifically, for example, a reference voltage is set between the peak point of the waveform of the counter electromotive force of the Fig. 5(A) and the peak point of the waveform of the counter electromotive force of the Fig. 5(B). Then, after the actuator 106 oscillates, set the digital signal to be high at the predetermined time. Then, if the waveform of the counter electromotive force [get across] crosses the reference voltage, it can be judged that there is no ink in the ink cartridge. If the waveform of the counter electromotive force does not [get across] crosses the reference voltage, it can be judged that there is ink in the ink cartridge.

Please amend page 44, second full paragraph as follows:

Furthermore, a part of the function of the recording apparatus control unit 2000 may be sent from the information processing apparatus such as a server to a terminal such as a computer connected to the recording apparatus through an electric communication line as a program. In this case, by storing the latest function in the recording apparatus of a computer which is easily sent from a server through an electric communication line, the recording apparatus can always [performs] perform the latest function.

Please amend page 46, first full paragraph as follows:

When the liquid consumption status detecting unit 1200 outputs the judging result that there is no ink in the liquid container 1, the control unit 1400 controls the recording apparatus operation control unit 1402 to perform the predetermined low ink level corresponding process. The low ink level corresponding process is the process which [considers that] determines whether [the] there is [few] little ink [remained] remaining in the liquid container 1 and [stop]

stops or [restrain] restrains the operation of the recording apparatus such as inappropriate printing. The recording apparatus operation control unit 1402 performs the low ink level corresponding process by controlling the operations of the indicating process unit 1404, the printing operation control unit 1406, the ink supplementing process unit 1408, the cartridge exchanging process unit 1410 or printing data storing process unit 1412 based on the direction of the control unit 1400.

Please amend page 48, paragraph bridging pages 48 and 49 as follows:

Fig. 7 shows a block diagram of the other embodiment of the recording apparatus control unit 2002. In the present embodiment, three actuators 106A, 106B, and 106C are mounted on the liquid container 1. Three actuators 106A, 106B, and 106C are mounted on the different position in the direction along which the liquid decreases by the liquid consumption. The measuring circuit unit 802 shown in Fig. 7 includes activating voltage generating units 850A, 850B, and 850C, each of which provides the voltage that activates the actuator to [the] each of actuators 106A, 106B, and 106C which are mounted on the liquid container 1, respectively. The digital circuit unit 902 in the detecting circuit unit 1102 inputs each of the counter electromotive force [signal] signals generated by the actuators 106A, 106B, and 106C from the measuring circuit unit 802 and counts the number of [pulse] pulses within predetermined time range of each of the counter electromotive force [signal] signals. Furthermore, the liquid existence judging unit 1002 judges the existence of liquid in the liquid container 1 based on [the] each of the count value of the counter electromotive force signal output from the digital circuit unit 902. Because each of a plurality of actuators is mounted on the different positions along the liquid decreasing direction in the present embodiment, the liquid consumption status at each of the mounting [position] positions of the actuator can be detected step by step. Because the configuration of the recording apparatus control unit 2002 other than the liquid consumption status detecting unit 1202 is the same as the configuration of the recording apparatus control unit 2000 shown in Fig. 6, the explanation of which will be omitted.

Please amend page 49, first full paragraph as follows:

The output signal of the actuator is different and depends on whether the liquid level is higher or lower than the level of the mounting position of the actuator. For example, the frequency or amplitude of the detected counter electromotive force changes greatly, and the detection signal changes according to the changes of the frequency or amplitude of the counter electromotive force. The liquid consumption status detecting unit 1202 can judge whether the liquid level has been passed through [the] each level of the mounting position of the actuator 106A, 106B, and 106C based on the detection signal. The detection process is performed periodically, at the previously determined timing.

Please amend page 50, third full paragraph as follows:

According to the present embodiment, because the detection position is switched downward sequentially, all the [actuator] actuators 106 [does] do not have to operate all the time, and the frequency of the operation of the actuator 106 decreases. Therefore, the quantity of data to be processed in the control unit 1400 can be reduced. As a result, the detection process does not decrease the throughput of the printing operation.

Please amend page 50, fourth full paragraph as follows:

In the present embodiment, the number of [actuator] actuators is three. However, the numbers of actuators 106 can be any number if it is three or more than three. Moreover, the interval of the mounting position of the actuator does not have to be constant. For example, it is preferable to arrange the interval of the actuators narrower as the [decrease of the] liquid level decreases. The variation shown above can be similarly applied to the following other embodiments.

Please amend page 51, second full paragraph as follows:

The control circuit unit 1502 of the recording apparatus control unit 2000 shown in Fig. 8 [no] not only has the element comprised in the recording apparatus control unit 2000 shown in Fig. 6 but further has a liquid discharging counter 1450, a liquid consumption quantity calculating unit 1452, and a cleaning control unit 1442. The liquid discharging counter 1450 counts the number of ink [drop] drops discharged from the head 1300. The liquid consumption quantity calculating unit 1452 calculates the quantity of ink consumption based on the number of

ink [drop] drops counted by the liquid discharging counter 1450. The cleaning control unit 1442 controls the cleaning driving unit 1432 based on the ink consumption status detected by the liquid consumption status detecting unit 1210. Furthermore, the detecting circuit unit 1104 includes a liquid consumption status correcting unit 1010 which corrects the number of ink [drop] drops discharged from the head 1300 that is counted by the liquid discharging counter 1450 based on the ink consumption status detected by the actuator 106.

Please amend page 51, paragraph bridging pages 51 and 52 as follows:

Next, the operation of the element newly added in Fig. 8 will be explained. The liquid discharging counter 1450 counts the number of ink [drop] drops discharged from the head 1300 during the printing and outputs to the liquid consumption quantity calculating unit 1452. The liquid consumption quantity calculating unit 1452 calculates the ink quantity discharged from the head 1300 based on the count value of the liquid discharging counter 1450. Furthermore, ink is also consumed by [a] flushing operation. The flushing operation recovers an uneven meniscus around the nozzle opening of the head 1300 and prevents the clogging of the ink in the nozzle opening by discharging the ink drop idly by applying the driving signal, which is not related to the printing operation, to head 1300. Therefore, the liquid discharging counter 1450 also counts the number of the discharged ink [drop] drops by the flushing operation and outputs to the liquid consumption quantity calculating unit 1452. The liquid consumption quantity calculating unit 1452 calculates the ink consumption quantity from the number of ink drops discharged from the head 1300 by the printing operation and the flushing operation and outputs the calculated ink consumption quantity to the liquid consumption status correcting unit 1010. The ink quantity calculated by the liquid consumption quantity calculating unit 1452 is displayed by the display 1416 of the indicating process unit 1404.

Please amend page 53, first full paragraph as follows:

The reason for using three outputs [form] from the liquid existence judging unit 1000, the liquid consumption quantity calculating unit 1452, and the cleaning control unit 1442 for detecting the ink consumption status will be explained in following. The output of the liquid existence judging unit 1000 is the information which is obtained by actually measuring the level

of liquid surface at the mounting position of the actuator 106. On the other hand, the outputs of the liquid consumption quantity calculating unit 1452 and the cleaning control unit 1442 are ink consumption quantity which is estimated [by calculated] from the number of ink [drop] drops counted by the liquid discharging counter 1450 and driving time of the pump 1434. This calculated value may cause an error because of the changes of the form of printing of the user or the using environment, for example, [the] changes of the pressure inside the ink cartridge or the viscosity of ink caused by [the] extremes of room temperature [extreme] or the [elapsed] time elapsed after the [unseal of] the ink cartridge has been unsealed. Therefore, the liquid consumption status correcting unit 1010 corrects the ink consumption quantity, which is calculated based on the output of the liquid consumption quantity calculating unit 1452 and the cleaning control unit 1442, with the judging result of the ink existence output from the liquid existence judging unit 1000. Furthermore, the liquid consumption status correcting unit 1010 corrects the parameter of the equation used by the liquid consumption quantity calculating unit 1452 for calculating the ink consumption quantity based on the judging result of the ink existence output from the liquid existence judging unit 1000. By correcting the parameter of equation, the equation is [adopted] adapted to the environment[,] in which the ink cartridge is used, so that the value obtained from the equation can be [closed] close to the value which is actually used.

Please amend page 56, first full paragraph as follows:

To store the consumption related information in the semiconductor memory device 7 is especially advantageous for the mounting and removing of the liquid container 1. The case is considered in which the liquid container 1 is removed from the ink jet recording apparatus when the liquid is consumed halfway. At this time, the semiconductor memory device 7, which stores the consumption related information, is always together with the liquid container 1. The liquid container 1 is mounted on the same ink jet recording apparatus again or is mounted on [the other] another ink jet recording apparatus. At this time, the consumption related information is read out from the semiconductor memory device 7, and the recording apparatus control unit 2006 operates based on the consumption related information [which is read out from the semiconductor memory device 7]. For example, if the consumption related information such that

the liquid container 1 mounted on the ink jet recording apparatus is empty or has only <u>a</u> small amount of residual ink, this consumption related information will be conveyed to <u>the</u> user. In this way, the former consumption related information of the liquid container 1 can be reliably used.